

Hunger and market dynamics in pre-modern communities: insights into the effects of market intervention from a multi-agent model

Ewert, Ulf Christian; Roehl, Mathias; Uhrmacher, Adelinde M.

Veröffentlichungsversion / Published Version

Zeitschriftenartikel / journal article

Zur Verfügung gestellt in Kooperation mit / provided in cooperation with:

GESIS - Leibniz-Institut für Sozialwissenschaften

Empfohlene Zitierung / Suggested Citation:

Ewert, U. C., Roehl, M., & Uhrmacher, A. M. (2007). Hunger and market dynamics in pre-modern communities: insights into the effects of market intervention from a multi-agent model. *Historical Social Research*, 32(4), 122-150. <https://doi.org/10.12759/hsr.32.2007.4.122-150>

Nutzungsbedingungen:

Dieser Text wird unter einer CC BY Lizenz (Namensnennung) zur Verfügung gestellt. Nähere Auskünfte zu den CC-Lizenzen finden Sie hier:
<https://creativecommons.org/licenses/by/4.0/deed.de>

Terms of use:

This document is made available under a CC BY Licence (Attribution). For more Information see:
<https://creativecommons.org/licenses/by/4.0>

Hunger and Market Dynamics in Pre-modern Communities: Insights into the Effects of Market Intervention from a Multi-agent Model

*Ulf Christian Ewert & Mathias Roehl &
Adeline M. Uhrmacher**

Abstract: »Hungerkrisen und Marktdynamik in vormoder-
nen Gemeinwesen: Erkenntnisse zur Wirkung von Markt-
interventionen auf Basis eines Multi-Agenten-Modells«. Food shortages and hunger had been a great threat to the standard of living in urban communities in the Middle Ages and in early modern times. In order to cope with this sort of critical events, local governments and municipal councils commonly tried to control market dynamics, but it is not clear, whether in cases like this the typical market reaction of rising prices of foodstuffs and wages could really be moderated in the long-run through an intervention in markets. In the present article, a simplified multi-agent-based model of the pre-modern urban economy is used which allows a simulation of effects that different strategies of crisis management had on the medium-term and long-range economic and demographic developments in an urban community experiencing a food shortage. Intervention in markets turns out to be a strategic choice of local authorities by which very likely wealth-destroying consequences of food shortages or even famines could be reduced to some extent. A successful intervention preventing a temporary food shortage turning into a substantial nutritional crisis nonetheless had to be goal-directed and of complex design, and

* Address all communications to: Ulf Christian Ewert, Philosophische Fakultät – Europäische Geschichte, Technische Universität Chemnitz, 09107 Chemnitz, Germany; e-mail: ulf-christian.ewert@phil.tu-chemnitz.de; Mathias Roehl, Arbeitsgruppe Modellierung und Simulation, Fakultät für Informatik und Elektrotechnik, Universität Rostock, Albert-Einstein-Straße 21, 18059 Rostock, Germany; e-mail: mroehl@informatik.uni-rostock.de; Adeline M. Uhrmacher, Arbeitsgruppe Modellierung und Simulation, Fakultät für Informatik und Elektrotechnik, Universität Rostock, Albert-Einstein-Straße 21, 18059 Rostock, Germany; e-mail: lin@informatik.uni-rostock.de.

showed its full wealth-keeping effects only after a considerably long period of time.

1. Adverse effects of food shortages: a late medieval example and some questions

A crisis in general puts the regular routines of a society and sometimes also the society itself at risk.¹ This was true indeed for medieval and early modern urban communities in Europe. However, most Europeans in early twentyfirst century do know the misery that is caused by epidemics, famines or natural disasters from television pictures only, pictures that usually are taken in distant Third World countries. The “New Orleans crisis” in the summer of 2005 (Knauer 2005; Birch/Wachter 2005; Giroux 2006; Bugliarello 2007), a total breakdown of urban life resulting from the hurricane “Katrina” and a flood that had set wide metropolitan areas under water presumably would be a powerful and instructive reminder for that European societies had been hit quite regularly by comparable disasters only very few generations back in time. Especially food shortages, hunger and epidemics had been a constant restriction and drawback to the standard of living that could be enjoyed by the people living in pre-modern cities and towns. In such events, which easily could turn into severe mortality crises, urban communities not only had to cope with price volatility and with excess mortality alone. Usually, communities had also to face a loss of births and the likelihood of a complete paralysis of local markets, circumstances that in the long-run very well could trigger demographic stagnation and a welfare-decreasing economic development (Walter/Schofield 1989). Very unstable market conditions and temporary excess mortality thus were a common daily life experience for Europeans until the epoch of Enlightenment and until the Industrial Revolution, a fact that nowadays simply has almost completely ceased from the cultural memory of Europe. Watching on television the extreme difficulties local authorities in New Orleans had to evacuate the city and to provide the inhabitants encircled by the water with foodstuffs and medical care therefore certainly was remarkable inasmuch as this real life scene was vividly recalling how easily exogenous shocks can endanger economic and social structures, even those of a highly developed society.²

¹ In contrast to the more neutral ancient greek meaning of the word, crisis is understood herein as an event having negative consequences and also being seen as such by the people concerned. (Koselleck 1982).

² Although consequences were much better managed, the earthquake in Kobe, Japan, in 1995 would be another quite recent example for a modern city in a highly industrialised country to be stricken by a natural disaster causing many casualties and big physical damages. See on this e.g. Horvich 2000.

Going again much further back in time, food shortages, famines and epidemics in late medieval urban communities do offer many insights into the dynamics of local markets during crises and the management of such critical events. Such an example for both the vulnerability to external shocks and the ability to compensate adverse impacts resulting from these shocks is the series of adverse events the Flemish city of Lille had been faced with in early fifteenth century. In fourteenth and early fifteenth centuries the city of Lille was quite a prosperous and wealthy town.³ Moreover, it was the centre of administration in the county of Flanders and then became, after Flanders had come under Burgundian rule, for some time the most important place of residence and administration within the northern territories of the dukes of Burgundy.⁴ Quite difficult times nevertheless then started in the year 1400 when a big fire destroyed large areas of the city. As a consequence, town markets of grain and labour broke down instantaneously, leaving behind people unemployed and in starvation and misery (Calonne/Clauzel 1974: 375 f., 378-382). For once, not a harvest failure but a disaster was responsible for severe shortcomings in the provision of inhabitants with food and for their temporary malnutrition. Only a few months later things became even worse with the advent of the second major wave of the bubonic plague in Northwestern Europe after 1348. By this epidemic many inhabitants of the city were killed, and the fact that citizens already had been weakened from the poor living conditions caused by the fire some months before certainly exacerbated the consequences of the outbreak of plague. The story of crises to occur recurrently then continued in 1408/09, in 1414/15 and again in 1436-39 with severe nutritional crises respectively, the latter of these having been a major European-wide famine that was caused by three consecutive harvest failures.⁵ In 1415/16 and in 1435 the situation got more complicated, because the areas nearby Lille had been subject to the pillage and ravage of through coming troops.⁶ These events of course were devastating for the town, again taking away many lives and hampering the standard

³ See on the economic development of the city Sivéry 1970: 235-257.

⁴ Philip the Bold, duke of Burgundy, who in 1369 married Margret of Flanders, daughter of the last Count of Flanders, Louis of Male, came to power in Flanders after his father-in-law had died in early 1384. Until the late 1420s and early 1430s when during the reign of his grandson Philip the Good other important northern territories like Brabant, Holland and Sealand were integrated into the Burgundian state, Lille functioned as the centre of administration in the North where the central institution of the chamber of revenues and accounts was located. (Sivéry 1970: 219-227, Vaughan 1975; Clauzel 1982, 1989 and 2004).

⁵ Even for late medieval standards the famine was perceived as being extremely harsh, which is also documented by a statement of duke Philip the Good saying that people in his northern territories were suffering from starvation as they had never done before. (Calonne/Clauzel 1974: 381 f.)

⁶ In late 1415 und early 1416 French troops beaten in Azincourt ravaged the landscape nearby Lille, and in September 1435, after the treaty of Arras between France and Burgundy, English troops moved through the county of Artois and West Flanders, pillaging and ravaging these areas. (Calonne/Clauzel 1974: 380 f.)

of living for all surviving inhabitants for many years to come (Calonne/Clauzel 1974: 376 f.).

These examples from late medieval Lille underline that food shortages due to whatever causes in pre-modern urban communities certainly were a serious threat not only to the lives of citizens but also to the structure of the urban economy, therefore reducing the standard of living of people in the short-term as well as in the medium-term and in the long-run. What is now questionable about this topic? That municipal councils tried to manage this sort of event is understandable and too obvious to dispute. And it is also clear, that cities and towns employed a set of distinct measures in order to get along with the possibly wealth-destroying market dynamics that usually unfolded in such situations. A short overview of the role the local grain market played in pre-modern towns and its dynamic behaviour in times of food shortage is given in the following section of this article. Potential objectives city governments aimed at with market intervention and with their approaches to crisis management are reexamined in this section as well. What seems not to be quite clear is whether such an intervention in markets was a successful strategy. Could the loss of welfare inhabitants usually suffered from during and after food shortages significantly be reduced through a manipulation of market mechanisms and the administration of markets?⁷ Of course, medieval and early modern time series of grain prices are very well displaying periods of price stability and periods of price volatility, but they do not allow for a valuable discrimination of whether the typical reduction in both level and variance of prices after times of dearth was due to crisis management itself or whether it was caused instead, either exogenously or endogenously, by other factors. A downward shift in demand, a supply with grain imports or simply an excellent follow-up harvest can be such determinants independent from municipal crisis management initiatives. Hence, a modelling approach is taken herein allowing, based on a multi-agent model of a pre-modern urban economy, the simulation of market dynamics during and after a food shortage. With this particular approach the relative impact of market intervention can be assessed in a comparison of simulated alternative paths of market development. The model is presented in section 3 below. In section 4 some results from the simulation of different crisis management scenarios are discussed.

2. The management of food shortage and hunger: a seemingly never ending pre-modern story

In pre-modern urban communities provisioning citizens with sufficient quantities of food was a key element with respect to the determination of living stan-

⁷ This question is also raised in Persson 1999: 88.

dards. Well into the nineteenth century food shortages and hunger were nonetheless a quite regular experience of city dwellers. Only with industrialisation starting in nineteenth century and with modern economic growth⁸ it became possible for Europeans to escape from hunger permanently (Fogel 1992, Fogel 2004). It is also worthwhile mentioning, that the resurgence of urban settlements in the Middle Ages as an alternative economic, social and political model to feudalism had been promoted by some profound structural changes. These changes in general lifted the standard of living of European populations: a significant upward shift in agricultural productivity in eleventh and twelfth centuries that was due to several technological advances⁹ and an improvement in climate has caused population growth. And it also enabled a substantial though even still small part of the population to be exempted from the production of basic nutrients and to afford a life in towns, producing and trading all sorts of commodities. As a result of these favourable living conditions until around the early fourteenth century thousands of towns were newly founded all across western and central Europe and interregional and long-distance trade has been revived in the so-called “Commercial Revolution”.¹⁰ Agricultural productivity could not be increased much thereafter until only the eighteenth century (Campbell/Overton 1991, Clark 1992). And the substantial climatic degradation which is known as the “Little Ice Age” and lasted for roughly 500 years reaching its minimum temperaturewise in seventeenth and early eighteenth centuries¹¹, agricultural production and therefore also the provision of the population with foodstuffs became a subject to severe and regular drawbacks, more than it probably had been before. As a consequence, the standard of living of people in terms of their nutritional status was depressed, which in part can be traced by a secular decline in human height.¹²

⁸ »Modern economic growth« is a concept designed to discriminate in a typifying manner the pattern of economic and population growth that had evolved beginning with the industrialisation from the growth pattern European economies had experienced before. Apart from being characterised by high growth rates of both income and population, by changes in the sectoral composition of the economy and by increases in the productivity and in the degree of market integration, this »modern« growth pattern is, for a considerable period of time at least, also self-enhancing. (Kuznets 1973)

⁹ Lopez 1976 [1998], Chapter 2: The Growth of Self-Centered Agriculture, 27-55.

¹⁰ See on this in general Lopez 1976 [1998].

¹¹ See on the development of temperature and precipitation during the last millenium Glaser 1997, Glaser/Beyer/Beck 1999 and Glaser 2001: 181. Le Roy Ladurie 2004 also provides an in-depth discussion of this climatic change and the social consequences resulting from it.

¹² See on the impact climate had on population development in pre-modern Europe Lee 1981; Galloway 1986 and 1988; Grove 2002. Considerations on the long-run changes in human height in Europe are given by Koepke/Baten 2005. As height to some extent mirrors the impact of environmental factors to which humans have been exposed to during their growth phase, average height can be taken as a proxy-measure for the net-nutritional status of a population. A secular decrease in height during the »Little Ice Age« can only be inferred to with indirect evidence. Such an indirect evidence is, that Europeans seemingly grew relatively tall before the »Little Ice Age« (Steckel 2004), that they were severely stunted in late

A causal nexus between the relative overall stagnation in both population growth and economic growth which can be observed during late Middle Ages and in early modern times and quite adverse living conditions was first claimed by the English scholar Thomas Robert Malthus. In his *Essay on the principle of population* published in 1798 (Malthus 1798 [1976]). Malthus developed a framework in which he systematically described the ups and downs in the level of the standard of living over time. He derived a plausible explanation by assuming the population in general tending to grow more rapidly than the supporting resources which are necessary for a sufficient supply with food. As a consequence, food shortages and nutritional crises develop, forcing people to the edge of subsistence or even below this level. In the view of Malthus these events together with epidemics were so-called *positive checks* to population growth during which the population number was temporarily reduced through excess mortality to a feasible number again. In the long-run, this negative feedback loop kept population and the economy in a balance, but did not allow for either substantial economic growth or demographic expansion. It definitely comes with some irony, that Malthus published his study first at a time when the process of industrialisation just has set off, a structural economic change that made it later on possible for European populations to cope better and better with the threat of a nutritional crisis.

Bearing in mind the crucial importance of food provision in the pre-modern world, food markets naturally have to be the focus of attention. Via urban food markets the produce of the agricultural sector was distributed to its consumers in the sectors of production and services. Thus, food markets were one element by which the rural and urban spheres of the economy were linked.¹³ And as grain and bread are basic nutrients, of all food markets the market for grain was presumably most important and does have of course a prominent position within the analysis of pre-modern urban living standards. Many surviving long series of grain prices from the Middle Ages and from early modern times obviously provide a good empirical basis for such an analysis¹⁴, but this is certainly not the only reason why focussing especially on grain markets. Although harvest yields and levels of grain prices empirically were not perfectly correlated with each other, rising prices commonly were caused by substantial crop failures (Persson 1999: 62-63).¹⁵ It is also known, that consumers usually reacted

seventeenth and early eighteenth centuries (Komlos 2003; Ewert 2004) and still remained relatively small also in mid-eighteenth century (Baten 2001).

¹³ Cf. for this the chapters in Chartres 1990.

¹⁴ See in general Braudel/Spooner 1967. Of course, only few of the numerous examples can be named here: Goubert 1960 (Beauvais in seventeenth and eighteenth centuries); Mestayer 1963 (Douai 1329-1793); Sivéry 1965 (Valenciennes in fourteenth and fifteenth centuries); Frêche/Frêche 1967 (Toulouse 1486-1868); Baulant 1968 (Paris 1431-1788); Tits-Dieuaide 1975 (Brabant and Flanders in fifteenth century); Ebeling/Irsigler 1977 (Cologne 1368-1797).

¹⁵ See also Hoskins 1964 and 1968.

inelastically to increases in grain or bread prices because of the basic nature of these foodstuffs.¹⁶ Price movements for grain and bread and the quantities traded therefore do pretty much reflect changes in the availability of basic foodstuffs, and it can be inferred from this, with a sufficient degree of accuracy at least, whether or not citizens were able to meet the level of subsistence.

What could have been done to ensure the provision of (urban) populations with grain? And which options commonly were realised to do so? In the case of Lille several reactions of the municipal council can be observed. During the famine of 1436/39 grain was publicly provided and private persons who owned grain were ordered to sell their inventories for a “fair” price. Grain exports from the city were prohibited at the same time, the grain market was monitored and bakers were ordered to bake specific types and sizes of their bread and to use the more expensive wheat for the production of cakes only (Cailionne/Clauzel 1974: 381 f., Clauzel 1982: 213). This set of measures implemented in late medieval Lille gives quite a good picture of what public intervention in pre-modern urban communities was about. This picture is in total accordance with the well-known and well-established fact that local governments tried to smooth erratic price movements both by closely monitoring markets and through intervening in the market mechanism.¹⁷ A stereotyped and quite classical reaction was the public supply of grain that had been put to stock beforehand. This practice of running public granaries (Erjncs/Persson 1999) goes back to ancient times (Garnsey 1988) and was in medieval Europe most developed in the Italian urban communities and city states at first. The effects of the storage of grain on market dynamics can be very well grasped with historical data on prices. Time series of grain prices are typically characterised by serial correlation, the main reason for that being changes in stocks of grain within towns. Prices rose because of a harvest failure in one year, but they usually remained at a high level even if next year’s harvest did not fail again. Supply from the already depleted granaries then was no longer possible and an increase in demand in order to restock granaries reduced the quantities of grain that were available to inhabitants immediately furthermore, putting the grain price under additional pressure. Vice versa, an excellent harvest not only led to decreases in the price of grain in that particular year, it could keep prices at a fairly low level also in the following year, because by storing it grain could be carried over from one harvest period to the next. Thus, increasing the quantities of grain to be traded on the market helped to lower prices in the short-term (Persson 1999: 55). And it was because of these decreases in price why the

¹⁶ Newer estimates of the elasticity of demand for grain derived from early modern and nineteenth century data from England, Southern Scandinavia, Central France (Bourges) and Southwest France (Bordeaux) are given in Persson 1999: 52-54. All raw estimates lie between -0.2 and -0.9, but for Scandinavia the estimate is corrected for the impact of trade and inventory to a more plausible value of around -0.6.

¹⁷ See on this in general Basini 1960; Ebeling 1979; Outhwait 1981; Matozzi 1983; McCloskey/Nash 1984; Nielsen 1997.

provision of the population with food could be secured and why it also was possible to reduce the likelihood for market take-overs of private merchants and for huge profits to be made by them from speculation.¹⁸

What were the likely objectives of municipal councils and local governments when being faced with a food shortage? And for what reason municipal councils were doing this? Although initially being thought as a societal model with members possessing an equal juridicial status, the immense economic and social dynamics connected to it had produced all across Europe already in the late Middle Ages urban communities in which social structure now was highly hierarchical and segregated. Municipal councils typically recruited their members from the social élites of the town, these encompassing a limited number of leading families and forming dense social networks and rather closed circles which hardly could be entered by newcomers. As usually these ruling élites, merchants for instance, had strong economic and political interests, a plausible common statement to be made regarding their objective would be assuming them to have had a primary concern about preserving their political legitimacy in order to stay in a powerful and influential position. Holding such a position was the prerequisite for fulfilling economic interests. In terms of political economy this behaviour can be described as rent seeking, because members of municipal councils could call on income derived from the use of their political influence for sharing vested or even obvious economic interests.¹⁹ Thus, discontent within the urban population, that very likely could be caused by unfavourable market dynamics and shortages of food provision, had in any case to be avoided. Smoothing price volatility, providing people with food and administering markets were certainly strategies for municipal councils that were suitable to prevent upheaval and uprising and to reject market take-overs by single merchants. Regulating markets also was good at making believe inhabitants suffering from continuous price instability that insider trading and speculation was under control (Persson 1999: 75). In addition, by ensuring a certain

¹⁸ Persson 1999: 62-64, using mid-seventeenth century grain prices from Southern Scandinavia, shows that even in a series of consecutive bad harvests – the »seven lean years« as they were labelled in early modern times with a reminiscence to the famous story of the Old Testament – food shortage in principle could have been smoothed out in the long-run by a proper management of grain stocks. In this example (1645-1651) the lack of available grain aggregated over time counted for only between a half and a full year of consumption which not automatically would have caused deprivation, because the single spells of dearth were much shorter. Deprivation was a consequence only of the extreme short-term rises of grain prices. See also Persson 1996.

¹⁹ In modern societies rent seeking commonly describes private persons' aims at capturing monopoly rents on a particular market with the help of politicians who had been persuaded by these persons to procreate and to protect such monopolies (Tollison 1982). As in pre-modern societies and urban communities there was no such clear-cut distinction between the private and the public sphere, the term »rent seeking« can be used under these circumstances to describe attempts of persons in influential political positions to shape urban institutions in a way that these institutions can fulfill a person's own private interests (Lehmann 2004: 46).

level of consumption the price stabilising attempts of municipal councils generated a positive external effect concerning the nutritional status of citizens and their standard of living (Ravaillon 1988). Through extended stints of malnutrition during the human growth period not only the final height that can be attained, but also health status and even life expectation for the remaining life of people are negatively affected.²⁰ By focussing on price stabilisation municipal councils also relieved in part such spells of malnutrition and delivered a public good insofar as this was beneficial for all citizens and thus of non-exclusive nature (Persson 1999: 72). This notwithstanding, very unlikely the preservation of the inhabitants' health status itself was a primary concern of municipal councils in medieval and early modern towns. Contributing to higher living standards instead was more or less a by-product of their short-term economic and political aims. With rent seeking it was first of all necessary to keep the current distribution of political and economic power in a balance. A population in the long run being healthier was of no obvious additional value in such a rationale.

3. Modelling markets and market dynamics: a multi-agent-approach

For purposes of assessment and analysis of the implications that market interventions had during food shortages and famines, a multi-agent-based simulation model of a pre-modern urban economy is used. This model is built on the grounds of the behavioural concept of rational choice, this implying the standard assumptions made in economic theory about the decision making of producers and consumers.²¹ It is implemented on the computer in JAMES, a Java-based *Agent Modelling Environment for Simulation*, which supports the distributed, parallel execution and testing of multiple heterogeneous, for instance either reactive, deliberative or hybrid agents (Schattenberg/Uhrmacher 2001).

This model of a pre-modern urban economy consists of several markets and different actor groups. Each of these groups comprises a set of individual households and they vary regarding the preferences and the behavioural patterns of their respective members. As such groups of actors merchants, craftsmen and labourers are distinguished. In the urban economy modelled that way merchants are responsible for the citizens' provision with grain. Craftsmen produce commodities and services, which they sell to the other agents in the economy. Craftsmen and merchants hire labourers, who form the third actor group, for their businesses, enabling the labourers to earn money to buy grain,

²⁰ See for a longer discussion of this argument Tanner 1994 and Persson 1999: 31-39.

²¹ See for a more detailed description of the structure of this model also Ewert/Roehl/Uhrmacher 2001 and 2003.

consumer products and services. Extending an earlier version of the model (Ewert/Roehl/Uhrmacher 2001 and 2003), each household now is modelled in greater detail and embraces itself a number of individuals, at least one female or male adult. If both a female and a male adult are present and a sufficient amount of grain can be purchased, new children are born with a certain probability depending on the number of children already living in the household and the time having passed since birth of the last child. Children having reached the age of 16 are announced to the marriage market of the model. In case of marriage the child and its spouse leave their according parental households and a new household is created. Mortality events are calculated for each individual depending on its age and whether the subsistence level has been met. If both adult persons of a household have died, the whole household vanishes.

Merchants, craftsmen and labourers are modelled as utility-based and reactive agents. In an economic theoretical framework this means assuming rational choices of agents and expecting them to maximise their utility and their profits. This rational economic behaviour of all agents is coordinated by the institution of markets where agents sell and buy goods. The supply and the demand of grain, commodities, services and labour is assumed to follow the basic principles that can be derived from neoclassical economic theory. Suppliers want to maximise their profits by selling their products and assets, and consumers want to maximise the utility they derive from consuming grain or other commodities instead, respectively. Basically, this rule implies, that in general consumers increase their demand for goods with decreasing prices and reduce it with increasing prices, whereas producers increase their supply of goods with rising prices and vice versa.²² Since agents interact with each other via the markets in this urban economy, price dynamics are driven by the ratio of supply to demand. Market clearing prices can be identified as those prices for which supply and demand quantities would be identical so that a particular good can be exchanged for money.²³ Agents are in a sense reactive insofar as their decisions are determined by income and price level. Actions to be taken on all markets are calculated for each household in the model.

Besides these numerous reactive agents classified into the three actor groups described above a deliberative single agent is added to the model, who represents a group of decision makers within the urban society and can be described as the town's local authorities or local government. In Lille for instance the municipal administration called *magistrat*, *échevinage* or *loy* in late fourteenth and early fifteenth centuries had more than forty members in total, but the important body of decision was the municipal council called the *collège des douze échevins*, which consisted of twelve citizens from honourable families of

²² See on this in general Varian 1999. In the present model a Cobb-Douglas function with labour input only is assumed for production, whereas consumer decisions are modelled in a Klein-Rubin utility function (Ewert/Roehl/Uhrmacher 2003: 178-181).

²³ See on the theory of competitive markets Gravelle/Rees 2004: 170-189.

the city and changed composition once a year at the date of All Saints.²⁴ The local authorities do raise their funds by collecting taxes, and in contrast to the other agents in the model, who only can react to market dynamics, this particular agent not only is capable of deliberately affecting market developments through interventions, but is also allowed to administer markets and to implement other regulations conditioning the economic behaviour of all other agents. As it was commonly the case in late medieval and early modern urban communities, in Lille the municipal administration was responsible for the city's finances and its bookkeeping. The council levied direct taxes from households (*taille*) and indirect taxes (*assise*) from the ongoing commerce of grain, wine and beer on the markets of the city (Clauzel 1982: 65-67). The internal structure of this agent, that is its behavioural pattern, thus embraces beliefs, desires and intentions.²⁵ It is assumed furthermore, that in the event of a nutritional crisis the local authorities' main objective is to stabilise prices, and as a consequence consumption and production, and to protect the assets and the state of welfare of citizens to the largest degree possible, because otherwise citizens are likely to revolt threatening the political legitimacy of the municipal council.²⁶ The local authorities agent in the model is therefore focussing the activities on the development of the citizens' satisfaction with their actual state of welfare, this being based on their perception of relative changes in wealth over time.²⁷ The structure of the model is schematically displayed in Figure 1.

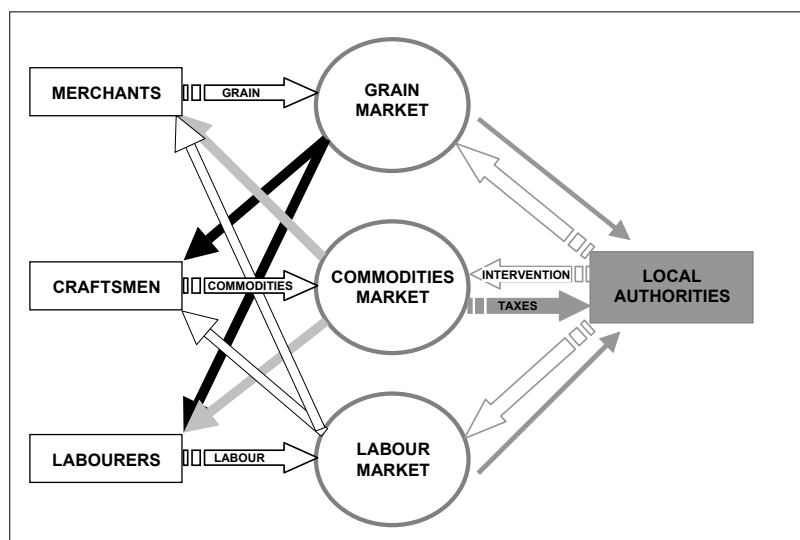
²⁴ The recruitment of the members of municipal council in addition was influenced by the duke of Burgundy, who was the lord and official owner of the city (Clauzel 1982: 63-84). This right was based on a contract between the community of Lille and the countess of Flanders dating back to the year 1235 (Sivéry 1970: 288 f).

²⁵ Agents of this kind are called BDI-agents, the »BDI« standing for beliefs, desires and intentions. With »beliefs« the type of information the agent has on the actual state of reality is described, whereas the way the agent would like reality to look like is called »desires«. »Intentions« are those desires an agent has committed itself to pursue. Typically with this a plan is associated with the purpose of changing reality such that its future state matches the agent's »desires« (Bratman 1987).

²⁶ The municipal council of Lille for instance fixed the amount of grain necessary for subsistence to four *rasières* of grain for each person per annum. This accounted for about 0.75 litres of grain each day. This level could be reduced to only three *rasières* if a food shortage lasted for longer time (Marquant 1940: 126).

²⁷ From a historical point of view it is of course quite simplifying to assume local authorities being a single agent. Not only was power in pre-modern urban communities usually executed by social élites, but also the members of this leading group often each had conflicting purposes. However, assuming a rent seeking behaviour of the members of the leading political class, that is expecting them to have used their political competence to fulfil vested economic interests, would mean that only decisions would have been taken by which each member believed to maximise his political rent. Thus, members of a municipal council had to compromise, otherwise no specific action could have been taken by the council. Modelling the local authorities as one agent only nonetheless is justified from both the historical and the modelling perspective insofar as the focus of analysis herein is on the impact decisions had on market intervention, rather than on explaining the process of decision making.

Figure 1: Markets, agents and actor groups, and their markets interactions



This specification allows the simulation of market development in a pre-modern economy over time. Starting with different conditions potential outcomes can be traced and analysed. However, why using a simulation approach? Simulation techniques certainly are not a standard method in historical analysis. Only a few rare examples, historical simulations with a scientific background are found in the literature.²⁸ Nevertheless, applying simulation to the analysis of historical phenomena makes very much sense indeed, because simulation supports experiments with models and therefore makes it possible to analyse the dynamic behaviour of a particular system under study. “What if” scenarios can be explored, an approach to historical explanation by which real life historical processes can be evaluated through a comparison with a counterfactual world.²⁹ In the application of simulation techniques herein it is aimed at

²⁸ To name only two of these rare examples, these are for instance the simulation of the Industrial Revolution (see Komlos/Artzrouni 1990 and Komlos/Artzrouni 1994) and the analysis focussing on demographic stagnation in early modern German urban communities (see McIntosh 2001).

²⁹ The counterfactual approach is one of the characteristics – others are the use of economic theory, the explicit formulation of hypotheses, the explicit measurement and the use of econometric methods – of the so-called »New Economic History« that was initiated in late 1950s and early 1960s by the studies of Conrad and Meyer (1958) on the profitable nature of the slave economy in the antebellum United States and of Fogel (1964) on the role railways played in United States’ industrialisation. It is presumably also the most controversial of these methodological principles, although each historical causal explanation in a very strict sense is derived in a comparison of historical reality with an alternative realisation of

assessing possible effects of market interventions by the local authorities in a pre-modern urban community. How do economic variables change over time once a nutritional crisis has developed with and without interventions of the municipal council? What specific impact do different intervention strategies have? Econometric analysis of historical time series data can be an excellent approach to this as long as data are available. For the dynamics of grain markets this is a viable approach.³⁰ In contrast, precise and continuous data on many other economic variables, on population figures and on environmental factors which would be a necessary prerequisite for the estimation of market intervention effects are almost lacking.³¹ Simulation seems therefore to be an appropriate methodological choice to find an answer to these questions.

Why then using a multi-agent design? As is indicated with the *RoboCup Rescue* project multi-agent simulation approaches are quite popular in the context of crisis management.³² Regarding the analysis of systems the most important shortcoming of the more traditional simulation models is that they are restricted to the coverage of the system's macro-structures only. In such models macro-level dynamics are generated by defining functional relations between macro-level variables, a feature that is suitable of course to a wide range of problems in economic and social sciences.³³ In contrast, with a multi-agent design the prevailing focus on the macro-level of system is left behind. In such multi-agent models the macro-level dynamics do result from many single actions taken by the numerous agents on the micro-level of the system.³⁴ Concerning market processes this appears to be an approach to the modelling of (historical) reality that is much more adequate.³⁵ Moreover, the multi-agent design allows to explicitly include heterogeneity of the agents' behaviour into models instead of being forced to assume a single "representative" economic agent as is the case in classical macro-level oriented economic models. Whereas, for instance, all agents within one of the three actor groups of the

history, one that could have been possible, but in most explanations is not explicitly defined. (Sarrazin 1980: 82-86).

³⁰ See for instance the analysis of Bac/Chevet/Ghysels 2001 on Toulouse and Paris grain prices.

³¹ Persson 1999: pp. 88-89, calls on several cases from seventeenth and eighteenth centuries where it is to some extent possible to distinguish market dynamics with and without regulation and public intervention, but admits, that drops in price volatility that are observed cannot safely be attributed to a more intense market regime only.

³² *Robocup Rescue* is a multi-agent simulation framework which can simulate disasters and the coordination of the multiple rescue units that are employed in such situations. Also the project aims at replacing persons in rescue teams by robots and developing information systems that can assist rescue forces in their decision making. Cf. Takahashi et al. 2002.

³³ An example is the demographic-economic model of pre-industrial Netherlands in de Vries 1984/85.

³⁴ See on the logic of multi-agent models applied to phenomena discussed in social science in general Doran 1996; Epstein/Axtell 1996; Epstein 1999; Gilbert/Troitzsch 2005.

³⁵ The multi-agent method is applied in economics for a wide range of market problems to be modelled. See on this LeBaron 2000; Tesfatsion 2001.

present model share an identical behavioural pattern, each individual agent has different assets at hand, can be hit by a nutritional crisis to a different degree and can reach different levels of income by using assets in a different manner during the course of a simulation. Thus, individual situations, decision processes and activities can be described. The opportunity to capture heterogeneity becomes even more important in modelling the activities of the local authorities agent within the model. A particular local authorities' intervention in markets designed to help the members in one of the actor groups is not automatically beneficial for the members of other actor groups as well. Being without employment, a labourer agent would probably welcome a municipal job creation programme, whereas a craftsmen would face difficulties finding employees due to the crowding-out effect resulting from public labour market activities. Although even with the feature of including heterogeneity the structure of the herein proposed multi-agent model is still quite simple when compared to a very complex historical reality, this particular design nonetheless possesses many of the ingredients that did characterise the structure of economic interactions in pre-modern towns and the social composition of such communities. The rather simplified design of the model aims at balancing mathematical and computational tractability with the quest of historians for a more detailed description of the relevant markets and agents.

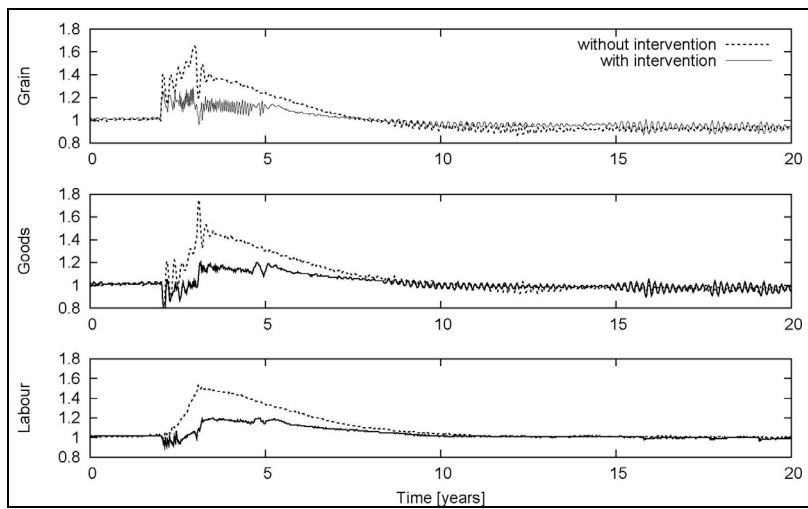
4. Market reaction patterns during crisis and thereafter: a comparison of scenarios

The multi-agent model is used for the simulation of market dynamics in pre-modern urban communities that followed food shortages. The population size of the model town is assumed to encompass between 15,000 and 17,000 inhabitants (individual agents) falling into 150 merchants' households, 250 households of craftsmen and 2,000 labourers' households, each household having about 4-5 children on average. These population figures do match those of late medieval Lille where population is estimated to have been in the range of 15,000-20,000 inhabitants (Sivéry 1970: 198-202, Clauzel 1982: 32 f.). By late medieval and pre-modern standards this would have been quite a big town. Once agents have been added to the population of the model with a certain probability – after they were “born”, so to speak –, they grow up, becoming older as the simulation process advances in time. Each simulation cycle is representing one week of physical time.

The growth of the population in the town depends partly on its natural reproduction rate and partly on the amount of in-migration, which in the model is exogenously given. A social differential in fertility is assumed inasmuch as a higher fertility rate is expected to pertain to the actor group of labourers

(Ewert/Roehl/Uhrmacher 2003: 185). The number of inhabitants is continuously reduced by death or emigration. With malnutrition the probability of death increases for all individuals. These mortality rates due to malnutrition are assumed to be extremely high for all types of agents. By assuming these high probabilities the well-established fact is taken into account that with malnutrition continuing for a considerable period of time people became more prone to plague and diseases³⁶ from which they die regardless of their social status. Nevertheless, merchants and craftsmen do have in general a higher potential to survive a nutritional crisis because their usually greater wealth allows them in an event like this to cope better with price instability and large increases in prices for foodstuffs.³⁷

Figure 2: Development of market prices



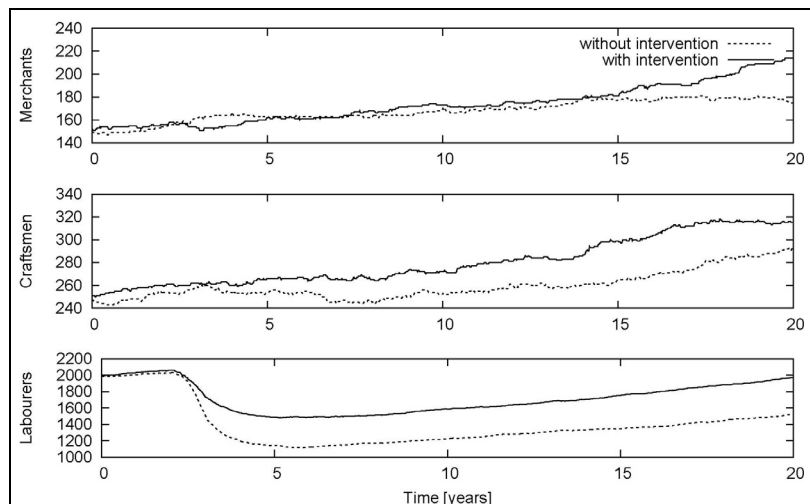
Such a food shortage is simulated by simply cutting back large proportions of the merchants' grain supply to the urban community for a particular period of time. Exactly this is the counter-factual which cannot be observed in historical reality, but is needed as a point of reference for the assessment of market dynamics under a public intervention regime. In this example the food shortages lasts for one year of physical time or, in terms of simulation time, for 52 simulation cycles. As the provision of a pre-modern population with grain largely depended on the harvest cycle, a one-year-period was a quite typical

³⁶ Cf. Mokyr/O'Grada 2002, who can show this with statistics on the causes of death within the mid 1840's Irish potato famine.

³⁷ For merchants and craftsmen a probability of mortality of 0.95 is assumed, whereas for labourers it is 0.99 (Ewert/Roehl/Uhrmacher 2003: 185).

time span for food shortages and famines. Very often, if next year's harvest was considerably better than the one before, a crisis could be immediately stopped by the time this harvest was available. Which effects of a simulated food shortage can be then observed? In Figure 2 price movements are shown.

Figure 3: Development of the population by actor groups during and after a major nutritional crisis



Because of the scarcity of grain, prices of grain rise tremendously (see top panel of Figure 2), forcing many of those persons who are most vulnerable regarding their status of welfare to living conditions below the subsistence level. Thus, by introducing exogenously conditions that lead to a temporary food shortage, a severe nutritional crisis then can develop endogenously in the model. The sharp increase of grain price in the simulation mirrors the dynamics that usually can be seen in historical price data. In the food shortage of Lille within early fifteenth century, the grain price tripled with respect to its pre-crisis level in the events of 1408/09 and 1414/15 and nearly quadrupled in the severe famine of 1436/39 (Calonne/Claudel 1974: 368). In this type of crisis the agents of the group of labourers are hit with the most hefty impact³⁸: about one third to one half of them die in the process because of malnutrition. A series of wages of carpenters and construction workers in fifteenth century Lille allows to calculate their nutritional opportunities. Facing a sharp increase in the price of grain these workers in the famine of 1436/39 were not able to buy enough foodstuff to meet the level of subsistence even when they earned

³⁸ This result corresponds to findings from the analysis of pre-modern food shortages (Persson 1999: 63-64).

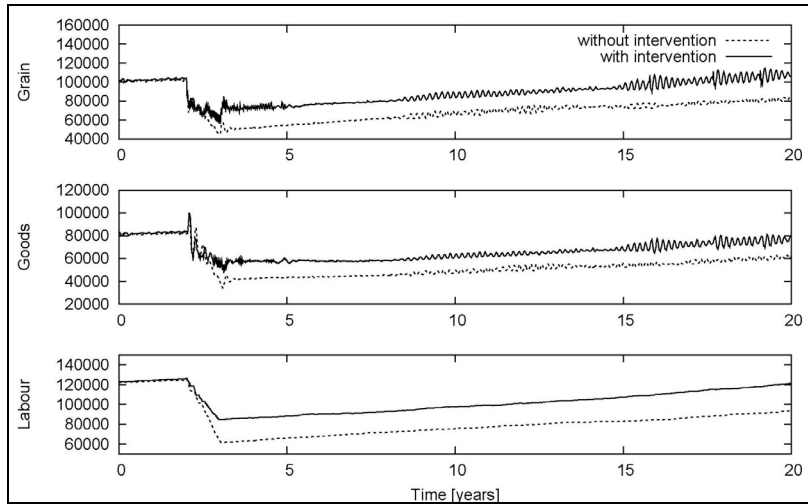
money (Calonne/Clauzel 1974: 377). The development of population figures for all actor groups derived from this simulation is displayed in Figure 3.³⁹ At least in the aftermath of the famine of 1436/39 the population of Lille did not grow substantially for about two decades. This can indirectly be inferred from two indicators – the development of direct taxes and the annual number of new citizens. The influx of new citizens was relatively low for many years and the amount of direct taxes accounted by the municipal administration dropped sharply during the crisis, recovered thereafter quite quickly but remained on this level well into the 1450's (Sivéry 1970: 200; Clauzel 1982: 33 and 250, Figures I and II).

Since the loss of that many lives has a deep impact also on the other markets of the urban community, a nutritional crisis does affect the structure of the urban economy and can of course threaten its existence as a whole. Wages rise substantially following the increases in grain prices because of the diminished aggregated labour supply of the surviving labourers (see central panel of Figure 2). This effect can in part be seen for the Lille example in the aftermath of the food shortage of 1414/15 and the famine of 1436/39. The corn wage of carpenters and construction workers, that is the nominal wage expressed in amounts of grain that can be bought with it, increased in both cases after the crisis. In 1415, for instance, the higher summer wage was also paid during the winter (Calonne/Clauzel 1974: 375-377). In case the crisis lasts for a longer period, this change in the labour supply can lead to a situation where many craftsmen are no longer able to hold on to their production level and to sell commodities and services. Then also craftsmen slightly begin to experience difficulties in meeting the subsistence level of nutritional intake. Although in this particular scenario of a food shortage lasting for as long as one year the number of craftsmen is still only marginally affected, the production of goods however suffers to a considerable degree from the substantial lack in the number of labourers. Since the production technology is assumed to rely on labour as the sole input factor and in general cannot be changed immediately through technical innovations or by switching to capital input, production and supply of commodities and services drop to a persistently lower level than before. As a consequence, it takes for all markets about 5-10 years to reach the pre-crisis-level of equilibrium of market prices again. There is enough empirical evidence for an economic stagnation of the city of Lille in the aftermath of the severe famine of 1436/39. Again, this can be inferred from the taxes that were accounted by the municipal administration. The amount of taxes for the control of linen produced in the town broke down in 1439 and recovered again only in the late 1440's. The same holds for the development of the tax amount that was received from the control of meat that was sold on the town's market. Also, the amount of money that was earned by the community by selling rights to par-

³⁹ See on the demographic effects of famines the study of Cotts Watkins/Menken 1985.

participate in the market first dropped within crisis and then only slowly increased up to the late 1450's (Clauzel 1982: 263 f., Figures XX, XXI and XXV). The medium-term development in supply levels derived from simulation is depicted in Figure 4. In addition, these market disturbances cause a higher income disparity between and also within the actor groups because of the overproportional drop in the labourers' share of population, this disparity persisting for even longer than 10 years in the aftermath of a nutritional crisis.

Figure 4: Development of the overall supply on markets



What becomes different if local authorities intervene in market processes in such a scenario of a nutritional crisis? As has been pointed out before, medieval and early modern municipal councils and town officials employed a set of different intervention measures in reaction to food shortages and nutritional crises with excess mortality. Since a rent seeking behaviour of members of municipal councils is assumed, the main objective of local authorities will be to get market disturbances under control such that the different needs of distinct social groups could be balanced and the distribution of power within the town remains stable. In the present multi-agent model, the local authorities' capability of administering markets therefore is manifold, since it can influence market dynamics and price movements in several ways. In general, direct and indirect interventions have to be distinguished. The local authorities can try to influence price developments in grain and labour markets directly by setting upper limits to the movement of prices. They also can try to create indirectly a price level that would be more favourable to agents by engaging themselves as an economic agent on these markets, for instance by supplying grain from the public granaries to the population of the community or by opting for a job programme.

The reduction of taxes also would be a more indirect form of market intervention, because with such an attempt the incentive structure for agents would be altered. As seen above, the already mentioned series of food shortages and famines in early fifteenth century Lille is a good example for what measures commonly were taken by municipal councils in reaction to crisis. The set of instruments by which the market was organised consisted of orders, supporting measures and bans. The citizens were ordered to store themselves as much grain as they needed for a year. Granaries were restocked and grain was supplied by the community. Control of grain transports and the production of bread was intensified. Exports of grain were prohibited, speculation was prosecuted and speculators had to bear the risk of being expropriated. Public construction works were initiated in 1401/02 when parts of the city wall were reconstructed and in 1414 when the town's fortifications were mended and reinforced.⁴⁰

Given this historical example of using multiple measures, a fairly complex intervention strategy is tested against the non-intervention in markets.⁴¹ As the local authorities are implemented as a BDI-agent, they have to decide, based on their beliefs, upon whether to intervene in markets or not and in which specific way intervention could be done, such that their desires (objectives) are going to be fulfilled. These beliefs embrace the current economic and demographic development in the urban community as well as information about the citizens' contentment with this particular situation.⁴² The actual setting of a developing famine is characterised by extremely high grain prices, a situation that is satisfying for the merchants in the model, but is dissatisfactory for labourers. To prevent food riots and political upheaval, local authorities can employ at least two strategies. The public supply of grain from the granaries will of course decrease the grain price and thus satisfy labourers, but this crowding-out of merchants from the grain market certainly will also lead to an increasing dissat-

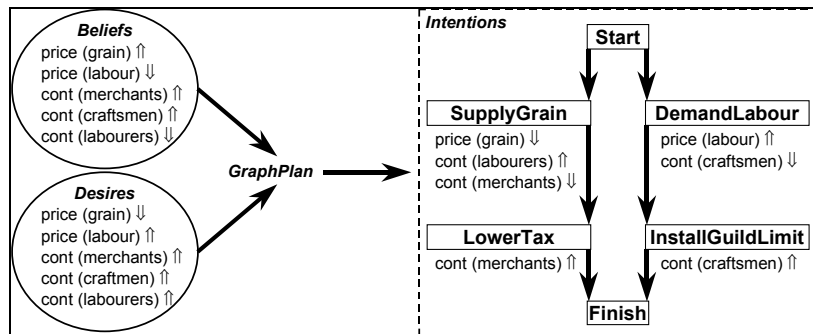
⁴⁰ Cf. Calonne/Clauzel 1974, pp. 378-382; Clauzel 1982, p. 213. The reinforcement of the town's fortification was ordered by the Burgundian duke John the Fearless in the view of the military conflict between England and France. The duke of Burgundy at that time was at peace with the French king and feared the invasion of English troops in West Flanders.

⁴¹ Also a simple response to price movements was tested in which intervention was restricted to public grain supply (Roehl 2002: 53-66 and 71-79). The results are not reported here, because compared to the complexity of real interventions the simple strategy obviously is unrealistic.

⁴² Assuming municipal councils to be primarily interested in price stability for selfish political and economic reasons means in the model that the local authorities agent is focussed on to which degree citizens are satisfied with their current state of welfare. Welfare is measured in terms of disposable income, which is real income minus the cost of the minimal demand necessary for staying above the subsistence level. Contentment is measured with a compound index aggregating changes in welfare as perceived by the citizens both over time – current wealth vs. wealth experienced one year earlier and short-term changes expressed as the moving average of income during the last month – and across social groups – that is income differentials to the average wealth in other groups relative to the situation one year before (Ewert/Roehl/Uhrmacher 2003: 181 f.).

isfaction of merchants. This discontent could be changed into contentment through reductions in taxes. The local authorities alternatively could increase the public demand for labour. Although in this case labourers would be given the opportunity to work and to earn money for enjoying a minimal standard of living at least, the crowding-out of craftsmen from the labour market now will leave behind this group of actors in strong discontent. Again, dissatisfaction could be turned into contentment by enabling craft guilds to install limits concerning the number of craftsmen to work and the number of new members. In pursuing the goal of keeping markets stable to the highest degree possible and thus contenting inhabitants, the local authorities do employ instruments which are described as so-called plan operators and which are used to plan strategies of intervention. Figure 5 shows part of a plan developed by the local authorities agent in the model in order to deal with price movements in a situation of food shortage. Such a plan is generated during simulation with the help of the program GraphPlan (Blum/Furst 1997).

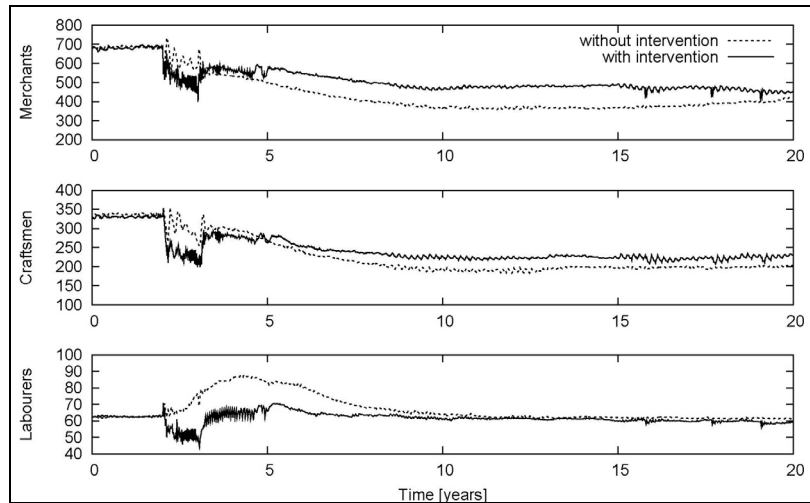
Figure 5: A plan developed by the local authorities to overcome negative effects of a nutritional crisis.



Simulation results show that planning local authorities who react to market disturbances in a complex manner are able to cope with a nutritional crisis rather successfully. The developed strategies combine a set of distinct instruments in a goal-directed manner, that is for instance influencing the grain price either directly or indirectly, but employing at the same time unemployed survivors in order to decrease the rising wages and probably lowering the tax burden. Simulation results show, that the outcome of such an intervention programme would be in many aspects favourable to the non-intervention strategy: prices do rise as well, but this increase is not as big as without intervention. From Figure 4 it can be seen, that also the overall quantities of grain and commodities supplied to the urban economy in the aftermath of the crisis are considerably higher than in a situation without intervention. Moreover, markets are

able to readjust faster to the pre-crisis equilibrium. Finally and most importantly, intervention strategy helps to save lives, with the “cost” of a smaller increase in the level of wealth of those surviving of course. Changes in the welfare status of the agents in the model, measured in terms of disposable income, are shown in Figure 6.

Figure 6: Development of the average level of welfare measured in terms of disposable household income



In the simulated scenario of a nutritional crisis that lasts for one year, the number of losses in the group of labourers can be reduced from between one half to one third without intervention to about a quarter with local authorities intervening in markets. Thus, the structure of the urban economy is affected to a much smaller degree, and traditional “winners” of a nutritional crisis cannot benefit as much as they would do if the local authorities refrain from implementing any measures of crisis management. Also, the increase in the disparity of income is smaller than without intervention. This has some long-run implications. As can be seen from the development of population numbers in Figure 2, in the complex and goal-directed public intervention scenario the share of craftsmen and merchants a decade after the famine will be somehow bigger than without intervention. In the absence of in-migration this would businesses force to substitute capital for labour setting off technological innovations. Assuming that merchants and craftsmen in terms of welfare are on average still better off than labourers, this would mean, that in any case income would be distributed more evenly across agents.

These results do allow for some tentative conclusions regarding the effect produced by crisis management through market intervention: first of all it is

obvious, that it takes some time to fully overcome a nutritional crisis with excess mortality. The crisis itself may have already stopped after several days, weeks or even months, by an excellent harvest for instance, as in pre-modern times has been often the case – in the case of Lille in 1436/39 it was because of grain imports from the Baltics, that misery in West Flanders ended (Calonne/Clauzel 1974: 382) –, but it takes several years to get markets back into the equilibrium they had been in before the outbreak of the crisis. The citizens of Lille experienced exactly this. Although grain prices fell fairly quickly after the famines of 1408/09 and 1436/39, wages remained for some years at the higher level they had climbed to during the respective crisis (Calonne/Clauzel 1974: 375 f.). With such permanent upshift in the cost of labour, of course also consumer goods in the medium-term did become more expensive. Secondly, the simulation results do indicate that market intervention in general seems to have an overall beneficial effect, since the pre-crisis equilibrium level of markets can then be obtained much faster than without any intervention. However, this strategy usually cannot be implemented without bearing any further costs. Intervention certainly has to be goal-directed and complex indeed, that is, local authorities have to engage in several markets at the same time in order to create a result that is positive for both the inhabitants and the members of municipal councils. The finding that intervention should be goal-directed and complex is coherent with findings of earlier psychological studies on how crises in complex and dynamic systems can be managed (Dörner 1989).

Could in the end the local authorities attain their primary goal to stabilise markets in order to prevent deprivation, discontent and possibly upheaval? Town officials of cities and towns in pre-modern Europe applied these routines in many cases, as for instance in the aftermath of the town fire in Lille, when the city council not only administered the city's grain market, but also intervened in the labour market. And they were doing it deliberately rather than intuitively, because although grain prices rose even with applying a more complex strategy of market intervention, the critical price cycles nevertheless had lower maxima and readjusted earlier to a level that was satisfactory for consumers. Thereby conflicting interests of social groups were balanced and the likelihood of a complete deprivation of inhabitants and of upheaval could be reduced. This notwithstanding, volatility of grain prices though in a much smaller range seems to be higher than without intervention. Thus, with market intervention smoothing critical peaks of the price movement might have been possible, but a stabilisation of prices in a way that consumers could rely on fixed constant prices cannot be reached. For the members of municipal councils who represented the town's social élite intervention was also a kind of trade-off between keeping current wealth in the short-term and enjoying welfare in the nearer future. As can be seen from the simulated development of welfare in Figure 6, in the complex intervention scenario also merchants and craftsmen experienced cutbacks in their welfare, but after some time of recovery they

could on average attain a higher welfare status than without any public intervention. This trade-off probably was also one critical element in the conservation of an established social hierarchy.

5. Crisis dynamics of historical urban markets: a plea for complex market intervention and for historical simulation?

With the purpose of analysing market dynamics during a food shortage and its aftermath in the pre-modern era, a multi-agent model is used. The model is built around three markets and distinguishes three groups of individual actors with similar but group-specific decision rules regarding the behaviour of exchange. An additional agent who is equipped with a limited set of means of intervention represents the local government. Even though this model is fairly complex in structure and dynamic behaviour, containing numerous agents acting independently from each other on the basis of relatively complex decision rules, compared to historical reality it still appears to be a rather simple image of a pre-modern town's social and economic structure. This agent-based approach to modelling and simulation nevertheless can add to the analysis of economic medium-term and long-term consequences of urban food shortages and famines.⁴³ Its design allows for a combination of knowledge about market dynamics, economic preferences and norms guiding the behaviour of individuals with respect to markets and governmental instruments that were employed in the pre-modern society. Fundamental characteristics of market dynamics in pre-modern urban communities can be accurately reproduced using this model for simulation, and the main simulation results do match experiences that many generations in Europe before the Industrial Revolution had made during and after food shortages.⁴⁴ It can therefore contribute to a better understanding of the management of historical nutritional crises, taking into account the different interwoven mechanisms that drove markets and the role of agents' preferences and activities during such events and in their aftermath.

Summing up the estimation results, three points have to be highlighted: firstly, a compensation of troubles caused by food shortages is possible, but cannot be done quickly. Secondly, compensation can be achieved through intervention in markets, then yielding an overall beneficial long-term effect and reducing the time re-equilibration usually takes. Thirdly, a complex and goal-oriented approach to market intervention has both short-term and long-term beneficial effects. These results are in accordance with findings of studies on

⁴³ Although using simulation techniques as well, the studies of Cotts Watkins/Menken 1985 and McIntosh 2001 are restricted to the demographic effects of crisis and famines.

⁴⁴ See for an overview of historical notes reporting the experiences of food shortages Livi-Bacci 1991.

modern famines in Third World countries (Persson 1999: 47). Since economic and social structures in Third World countries do resemble in many respects those of pre-modern Europe, this is not that much astonishing. As has been the case in medieval and early modern urban communities, in towns and cities of underdeveloped countries the majority of inhabitants consists of labourers and craftsmen who are heavily dependent on market provision of basic foodstuffs like grain, vegetables, meat or milk products for being able to meet their basic nutritional requirements. Quite comparable to pre-modern towns, the mortality rate of the urban population in general is at quite high level and commonly inhabitants are more prone to plague and diseases than is the rural population. These similarities in structure but also in reaction to crisis do underline that the analysis of famines in current underdeveloped countries are certainly of great importance for the understanding of the patterns of nutritional crises in the history of Europe.

There has been not much doubt about whether food shortages and nutritional crises are manageable, neither of theorists in modern social sciences nor of local authorities in historical practice. The much better performance of a complex market intervention strategy in comparison to the choice of non-intervention shows that intervention in markets is not a bad thing in itself, as neo-classical economic theorists have always been eager to emphasise. Given the plausible assumption that municipal councils in pre-modern urban communities for staying in power were primarily concerned about avoiding the immediate short-term consequences of food shortages, these very likely being a pronounced discontent and upheaval due to deprivation, the attempt at smoothing out extreme grain price volatility and balancing adverse spill-over effects to other markets at the same time was basically almost inevitable for municipal councils if they wanted to achieve this goal. Although being more or less a by-product, the positive long-term effects of this more complex, but nevertheless short-term-oriented crisis management presumably could also help municipal councils to keep their legitimacy and to remain in a ruling position. As the readjustment of the urban economy happened faster and interests of all social groups are balanced, the citizens' discontent with an initially unfavourable market development is much more limited.

Thus, apart from explaining historical strategy choices regarding crisis management, these findings at least do justify a plea for an intelligent intervention. Can the results be taken for a plea for historical simulation as well? Simulation allows to construct a counter-factual which then serves as a point of reference to observable real-life phenomena. Simulating different scenarios of market dynamics caused by a food shortage enables to compare distinct regimes of public intervention and to assess both the impact of public intervention relative to that of non-intervention and the pace of markets' readjustment to a pre-crisis equilibrium. These are features with respect to the role of market intervention, which are virtually impossible to be validated with historical data for simply

two reasons: one hardly finds an example where town officials in order to cope with a nutritional crisis refrained from intervention at all. Moreover, European towns and cities in the pre-modern era were hit by crises so frequently, that usually a crisis was not yet completely overcome when the next one already had started to develop again. Town fire, plague and several food shortages in early fifteenth century Lille are good examples for such a succession of critical events. In a historical simulation these features can be tested. Thus, although historical simulation certainly is limited in scope, providing historians with these powerful analytical capacities obviously justifies also a plea for the use of simulation methods in historical research.

References

- Bac, Catherine/Chevet, Jean-Michel/Ghysels, Eric (2001): „Time-Series Model with Periodic Stochastic Regime Switching, Part II: Applications to 16th- and 17th-Century Grain Prices“. In: *Macroeconomic Dynamics*. 5. S. 32-55.
- Basini, Gianluigi L. (1960): „L'uomo e il pane. Risorse, consumi e carenze alimentari della popolazione modenese nel cinque e seicento“. Mailand.
- Baten, Joerg (2001): „Climate, Grain Production and Nutritional Status in Southern Germany during the XVIIIth Century“. In: *Journal of European Economic History*. 30. S. 9-47.
- Baulant, Micheline (1968): „Les prix des grains à Paris de 1431 à 1788. Annales. Économies. Sociétés“. In: *Civilisations*. 23. S. 520-540.
- Birch, Eugenie L./Wachter, Susan M. (Hg.) (2005): „Rebuilding Urban Places after Disaster: Lessons from Hurricane Katrina“. New Orleans.
- Blum, Avrim/Furst, Merrick (1997): „Fast Planning Through Planning Graph Analysis“. In: *Artificial Intelligence*. 90. S. 281-300.
- Bratman, Michael E. (1987): „Intentions, Plans, and Practical Reasoning“. Cambridge.
- Braudel, Fernand/Spooner, Frank (1967): „Prices in Europe from 1450 to 1750“. In: Rich, E. E./Wilson, C. H. (Hg.): *The Economy of Expanding Europe in the Sixteenth and Seventeenth Centuries (The Cambridge Economic History of Europe IV)*. Cambridge. S. 374-486.
- Bugliarello, George (Hg.) (2007): „Perspectives on Hurricane Katrina“. *Technology in Society* 29/2 – Special issue. Amsterdam.
- Calonne, Sylvain/Clauzel, Denis (1974): „Conjuncture et société à Lille pendant la période bourguignonne“. In: *Revue du Nord*. 56. S. 365-384.
- Campbell, Bruce/Overton, Mark (Hg.) (1991): „Land, Labour, and Livestock: Historical Studies in European Agricultural Productivity“. Manchester.
- Chartres, John (Hg.) (1990): „Agricultural Markets and Trade 1500-1750“. In: *Chapters from the Agrarian History of England and Wales* 4. Cambridge.
- Clark, Gregory (1992): „The Economics of Exhaustion, the Postan Thesis, and the Agricultural Revolution“. In: *Journal of Economic History*. 52. S. 61-84.
- Clauzel, Denis (1982): *Finances et politique à Lille pendant la période bourguignonne*. Dunkerque.

- Clauzel, Denis (1989): „Seconde partie: l'âge des mutations (1328-1519)“. In: Platelle, Henri/Clauzel, Denis (Hg.): Des principautés à l'Empire de Charles-Quint (900-1519). Histoire des Provinces françaises du Nord 2. Lille. S. 117-268.
- Clauzel, Denis (2004): „Le roi, le prince et la ville: l'enjeu des réformes financières à Lille à la fin du moyen âge“. In: Cauchies, Jean-Marie (Hg.): Finances et financiers des princes et des villes à l'époque bourguignonne (Burgundica VIII). Turnhout. S. 41-61.
- Cotts Watkins, Susan/Menken, Jane (1985): „Famines in Historical Perspective“. In: Population and Development Review. 11. S. 647-675.
- de Vries, Jan (1984/85): „The Population and Economy of Preindustrial Netherlands“. In: Journal of Interdisciplinary History. 15. S. 661-682.
- Dörner, Dietrich (1989): „Die Logik des Mißlingens: Strategisches Denken in komplexen Situationen“. Hamburg.
- Doran, Jim (1996): „From Computer Simulation to Artificial Societies“. In: Simulation: Transactions of the Society for Computer Simulation International. 14 (2). S. 69-77.
- Ebeling, Dietrich (1979): „Versorgungskrisen und Versorgungspolitik während der zweiten Hälfte des 16. Jahrhunderts in Köln“. In: Zeitschrift für Agrargeschichte und Agrarsoziologie. 27. S. 32-59.
- Ebeling, Dietrich/Irsigler, Franz (1977): „Getreideumsatz, Getreide- und Brotpreise in Köln, 1368-1797“. Wien.
- Epstein, Joshua M. (1999): „Agent-Based Computational Models and Generative Social Science“. In: Complexity. 4 (5). S. 41-60.
- Epstein, Joshua M./Axtell, Robert (1996): „Growing Artificial Societies. Social Science from the Bottom Up“. Cambridge (MA). London.
- Erjñoes, Mette/Persson, Karl Gunnar (1999): „Grain Storage in Early Modern Europe“. In: Journal of Economic History. 59. S. 762-772.
- Ewert, Ulf Christian (2004): „The Biological Standard of Living in a Cold Century. Long-term Effects of Climate and the Economy on Average Height in Ancien Régime France“. In: Francia. 31 (2). S. 25-53.
- Ewert, Ulf Christian/Roehl, Mathias/Uhrmacher, Adelinde M. (2001): „The Role of Deliberative Agents in Analyzing Crisis Management in Pre-modern Towns“. In: Sozionik aktuell. 3. S. 43-57.
- Ewert, Ulf Christian/Roehl, Mathias/Uhrmacher, Adelinde M. (2003): „Consequences of Mortality Crises in Pre-modern European Towns: A Multiagent-based Simulation Approach“. In: Billari, Francesco/Prskawetz, Alexia (Hg.): Agent-based Computational Demography. Using Simulation to Improve Our Understanding of Demographic Behaviour. Berlin, Heidelberg. S. 175-196.
- Fogel, Robert W. (1964): „Railroads and American Economic Growth: Essays in Econometric History“. Baltimore.
- Fogel, Robert W. (1992): Second Thoughts on the European Escape from Hunger: Famines, Chronic Malnutrition, and Mortality Rates. In: Osmani, Siddiqur R. (Hg.): Nutrition and Poverty. Oxford. S. 243-286.
- Fogel, Robert W. (2004): The Escape from Hunger and Premature Death, 1700-2100 – Europe, America and the Third World. Cambridge.
- Frêche, Georges, Frêche, Genevieve (1967): „Les prix des grains, des vins et des légumes à Toulouse (1486-1868) – extraits des mercuriales (Travaux de recher-

- che de la Faculté de Droit et des Sciences Économiques de Paris, série Sciences Historiques 10)“. Paris.
- Galloway, Patrick R. (1986): „Long-term Fluctuations in Climate and Population in the Pre-industrial Era“. In: *Population and Development Review*. 12. S. 1-24.
- Galloway, Patrick R. (1988): „Basic Patterns in Annual Variations in Fertility, Nuptiality, Mortality and Prices in Pre-industrial Europe“. In: *Population Studies*. 42. S. 275-304.
- Garnsey, Peter (1988): *Famine and Food Supply in the Graeco-Roman World: Response to Risk and Crisis*. Cambridge.
- Gilbert, Nigel/Troitzsch, Klaus G. (2005): *Simulation for the Social Scientist*. 2nd edition. Maidenhead.
- Giroux, Henry A. (2006): *Stormy Weather: Katrina and the Politics of Disposability*. Boulder (CO).
- Glaser, Rüdiger (1997): „On the Course of Temperature in Central Europe since the Year 1000 A.D.“. In: *Historical Social Research*. 22 (1). S. 59-87.
- Glaser, Rüdiger (2001): *Klimageschichte Mitteleuropas. 1000 Jahre Wetter, Klima, Katastrophen*. Darmstadt.
- Glaser, Rüdiger/Beyer, Ulrike/Beck, Christoph (1999): „Die Temperaturentwicklung in Mitteleuropa seit dem Jahr 1000“. In: *Tübinger Geographische Studien*. 125. S. 23-46.
- Goubert, Pierre (1960): „Beauvais et le Beauvaisis de 1600 à 1730“. 2 vols.. Paris.
- Gravelle, Hugh/Rees, Ray (2004): „Microeconomics“. 3rd edition. Harlow.
- Grove, Jean (2002): „Climatic Change in Northern Europe over the Last Two Thousand Years and its Possible Influence on Human Activity“. In: Wefer, Gerold/Berger, Wolfgang H./Behre, Karl-Ernst/Jansen, Eystein (Hg.): *Climate Development and History of the North Atlantic Realm*. Berlin, Heidelberg. S. 313-326.
- Horwich, George (2000): „Economic Lessons of the Kobe Earthquake“. In: *Economic Development and Cultural Change*. 48. S. 521-542.
- Hoskins, William G. (1964): „Harvest Fluctuations and English Economic History, 1480-1690“. In: *Agricultural History Review*. 12. S. 28-46.
- Hoskins, William G. (1968): „Harvest Fluctuations and English Economic History, 1620-1759“. In: *Agricultural History Review*. 16. S. 15-31.
- Knauer, Kelly (Hg.) (2005): *Hurricane Katrina: The Storm that Changed America*. New York.
- Köpke, Nicola/Baten, Jörg (2005): „The Biological Standard of Living in Europe during the Last Two Millennia“. In: *European Review of Economic History*. 9. S. 61-95.
- Komlos, John (in collaboration with Hau, Nicole and Bourguinat, Nicolas) (2003): „An Anthropometric History of Early-modern France“. In: *European Review of Economic History*. 7. S. 153-189.
- Komlos, John/Artrouni, Marc (1990): „Mathematical Investigations of the Escape from the Malthusian Trap“. In: *Mathematical Population Studies*. 2. S. 269-287.
- Komlos, John/Artrouni, Marc (1994): „Ein Simulationsmodell der Industriellen Revolution“. In: *Vierteljahrschrift für Sozial- und Wirtschaftsgeschichte*. 81. S. 326-338.

- Koselleck, Reinhart (1982): „Krise“. In: Brunner, Otto/Conze, Werner/Koselleck, Reinhart (Hg.): *Geschichtliche Grundbegriffe. Historisches Lexikon zur politisch-sozialen Sprache in Deutschland*. 3. Stuttgart. S. 617-650.
- Kuznets, Simon (1973): „Modern Economic Growth: Findings and Reflections“. In: *American Economic Review*. 63. S. 247-258.
- LeBaron, Blake (2000): „Agent Based Computational Finance: Suggested Readings and Early Research“. In: *Journal of Economic Dynamics and Control*. 24. S. 679-702.
- Lee, Ronald (1981): „Short-term Variations in Vital Rates, Prices, and Weather“. In: Wrigley, Edward A./Schofield, Roger S. (Hg.): *The Population History of England, 1541-1871: A Reconstruction*. London. S. 356-410.
- Lehmann, Sybille (2004): „A Rent Seekers' Paradise, or Why There was No Revolution in Fifteenth- to Eighteenth Century Nuremberg“. In: Volckart, Oliver (Hg.): *The Institutional Analysis of History. Homo Oeconomicus XXI/1 – special edition*. Munich. S. 41-57.
- Le Roy Ladurie, Emmanuel (2004): *Histoire humaine et comparée du climat. I: Canicules et glaciers (XIII^e-XVIII^e siècles)*. Paris.
- Livi-Bacci, Massimo (1991): *Population and Nutrition. An Essay on European Demographic History*. Cambridge.
- Lopez, Robert S. (1976 [1998]): *The Commercial Revolution of the Middle Ages, 950-1350*. Cambridge [New York].
- Malthus, Thomas R. (1798 [1976]): *An Essay on the Principle of Population, as it Affects the Future of Society, with Remarks on the Speculations of Mr. Godwin, M. Condorcet, and other Writers*. New York.
- Marquant, Robert (1940): *La vie économique à Lille sous Philippe le Bon*. Paris.
- Mattozzi, Ivo (1983): „Il politico e il pane a Venezia, 1570-1650: calmieri e governo della sussistenza“. In: *Società e Storia*. 20. S. 271-303.
- McCloskey, Deirdre (früher Donald)/Nash, John (1984): „Corn at an Interest: The Extent and Cost of Grain Storage in Medieval England“. In: *American Economic Review*. 74. S. 174-187.
- McIntosh, Terence (2001): „Urban Demographic Stagnation in Early Modern Germany: A Simulation“. In: *Journal of Interdisciplinary History*. XXXI. S. 581-612.
- Mestayer, Monique (1963): „Les prix du blé et de l'avoine de 1329 à 1793“. In: *Revue du Nord*. 45. S. 157-176.
- Mokyr, Joel/Ó Gráda, Cormac (2002): „What Do People Die of during Famines: The Great Irish Famine in Comparative Perspective“. In: *European Review of Economic History*. 6. S. 339-363.
- Nielsen, Randall (1997): „Storage and English Government Intervention in Early Modern Grain Markets“. In: *Journal of Economic History*. 57. S. 1-33.
- Outhwaite, Richard B. (1981): „Dearth and Government Intervention in English Grain Markets, 1590-1700“. In: *Economic History Review*. 34. S. 389-406.
- Persson, Karl G. (1999): *Grain Markets in Europe, 1500-1900. Integration and Deregulation. Cambridge Studies in Modern Economic History 7*. Cambridge.
- Persson, Karl G. (1996): „The Seven Lean Years, Elasticity Traps, and Intervention in Grain Markets in Early Modern Europe“. In: *Economic History Review*. 49. S. 692-714.
- Ravallion, Martin (1987): *Markets and Famines*. Oxford.

- Roehl, Mathias (2002): Komponentenbasierte Modellierung und Simulation von Agenten. Diploma-Thesis. University of Rostock. Rostock.
- Sarrazin, Thilo (1980): „Theorien in der quantifizierenden Geschichtsforschung“. In: Rüsen, Jörn/Süssmuth, Hans (Hg.): Theorien in der Geschichtswissenschaft. Düsseldorf. S. 79-97.
- Schattenberg, Bernd/Uhrmacher, Adelinde M. (2001): „Planning Agents in JAMES“. In: Proceedings of the IEEE. 89(2). S. 158-173.
- Sivéry, Gérard (1965): L'évolution du prix du blé à Valenciennes aux XIV^e et XV^e siècles. *Revue du Nord*. 47. S. 177-194.
- Sivéry, Gérard (1970): „'Histoire économique et sociale' and 'Quelques aspects des institutions Lilloises au moyen âge'“. In: Trenard, Louis (Hg.): Histoire de Lille. 1: Des origines à l'avènement de Charles Quint. Lille. S. 111-304.
- Steckel, Richard H. (2004): „New Light on the 'Dark Ages': The Remarkably Tall Stature of European Men during the Medieval Era“. In: *Social Science History*. 28. S. 211-228.
- Takahashi, Tomoichi/Tadokoro, Satoshi/Ohta, Masayuki/Ito, Nobuhiro (2002): Agent Based Approach in Disaster Rescue Simulation – From Test-Bed of Multi-agent System to Practical Application. *RoboCup 2001 (Lecture Notes in Computer Science 2377)*. Berlin. S. 64-73.
- Tanner, James M. (1994): Introduction: Growth in Height as a Mirror of the Standard of Living. In: Komlos, John (Hg.): *Stature, Living Standards and Economic Development. Essays in Anthropometric History*. Chicago. S. 1-6.
- Tesfatsion, Leigh (2001): Introduction to the CE Special Issue on Agent-based Computational Economics. *Journal of Economic Dynamics and Control*. 25. S. 281-293.
- Tits-Dieuaide, Marie-Jeanne. (1975): La formation des prix céréalières en Brabant et en Flandre au XV^e siècle. Brüssel.
- Tollison, Robert D. (1982): „Rent Seeking: A Survey“. In: *Kyklos*. 35. S. 575-602.
- Varian, Hal R. (1999): *Intermediate Microeconomics. A Modern Approach*, 5th edition. New York.
- Vaughan, Richard (1975): *Valois Burgundy*. London.
- Walter, John/Schofield, Roger S. (1989): „Famine, Disease and Crisis Mortality in Early Modern Society“. In: Walter, John/Schofield, Roger S. (Hg.): *Famine, Disease and the Social Order in Early Modern Society*. Cambridge. S. 1-73.